27p

N63-12119
Code 1

SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY

Research in Space Science

SPECIAL REPORT

Number 109

OTS PRICE

XEROX $ 2.60 ph

MICROFILM $ 1.01 mf

December 21, 1962

CAMBRIDGE 38, MASSACHUSETTS

SAO Special Report No. 109

RE-ENTRY AND RECOVERY OF FRAGMENTS OF SATELLITE 1960 ϵ1

by

Charles A. Lundquist

Richard C. Vanderburgh

Walter A. Munn

David Tilles, Edward L. Fireman and James DeFelice

Smithsonian Institution
Astrophysical Observatory

Cambridge 38, Massachusetts

Table of Contents

Smithsonian Astrophysical Observatory Program for Observation, Recovery, and Scientific Utilization of Satellite Fragments
by Charles A. Lundquist.. 1

Sputnik IV Re-entry: The Role of Moonwatch
by Richard C. Vanderburgh...................................... 9

Field Investigation of Sputnik IV Sightings and Fragment Recoveries
by Walter A. Munn.. 15

Radioactivities in the Manitowoc Fragment
by David Tilles, Edward L. Fireman and James DeFelice.......... 21

Appendix 1... 23

SMITHSONIAN ASTROPHYSICAL OBSERVATORY PROGRAM FOR OBSERVATION, RECOVERY, AND SCIENTIFIC UTILIZATION OF SATELLITE FRAGMENTS[1]

Charles A. Lundquist[2]

On September 5, 1962, at about 09:50 UT, Satellite 1960 $\epsilon 1$ (Sputnik IV) re-entered the earth's atmosphere over North America, with many fragments reaching the end of their orbit over the State of Wisconsin. This re-entry was observed by the Milwaukee Moonwatch team. A steel body with mass 9.49 kg was subsequently found in a street of Manitowoc, Wis. Radioisotope analyses determined that this body had indeed been exposed to the radiation environment above the atmosphere. This determination led to the conclusion that the body was part of Sputnik IV.

This highly successful sequence of events (observation of re-entry, recovery of fragments, and scientific investigation) must be attributed to remarkably good fortune and to a determined effort by the Smithsonian Astrophysical Observatory. The Smithsonian satellite tracking stations and Moonwatch teams whenever possible observe satellite re-entries, investigate bright fireballs, and attempt to recover samples of recently fallen meteorites and satellites. For example, observations of the demise of Satellite 1957 $\beta 1$ were collected and reported (Jacchia, 1958). This program was also directly responsible for the acquisition of the Meteorite Ehole shortly after it fell (Fireman, 1962). However, until now the program had not been successful in recovering satellite fragments.

---

1 This work was supported in part by Grant NsG 87-60 from the National Aeronautics and Space Administration.

2 Assistant Director (Science), Smithsonian Astrophysical Observatory.

The efforts to recover satellite specimens were recently increased, owing partly to additional financial support and partly to the recognition that the number of re-entering satellites has increased to a point where the probability is significant for an occasional success. As the Observatory has, within its divisions, the capability to accomplish all essential phases of the program, it is a natural undertaking. The necessary orbital predictions can be routinely prepared by the Computations Division; observations can be initiated through the Moonwatch Division and the Baker-Nunn satellite tracking stations; search techniques prepared for the Meteorite Recovery Project can be applied to satellite fragments; a worldwide communication net is available; and finally, SAO has laboratories engaged in scientific investigations based on recovered specimens. The scientific results potentially obtainable from this program were judged to be sufficient to justify its adoption. This program to recover satellite fragments has also been recognized as complementary to the recently established Meteorite Recovery Project (NASA Grant NsG 291-62, July 1, 1962).

Included in this special report are detailed statements from several divisions of SAO that participated in the observation, recovery, and analysis of the fragments from Satellite 1960 $\epsilon 1$. The account presented by these reports carries the events only as far as identification of the objects as satellite fragments. It is perhaps worth noting that laboratory analyses of the first fragment were underway barely fifty hours after the demise of the satellite. In addition to the work at SAO, specimens of the satellite were distributed to various scientific institutions for their use and investigations. Results of these scientific studies using the fragments will follow later (see appendix 1).

The activities of SAO during these events were supported, in part, under grants from the National Aeronautics and Space Administration. Close liaison has been maintained with officials of NASA.

Sputnik IV (Satellite 1960 $\epsilon 1$)

Satellite 1960 $\epsilon 1$, placed in orbit on May 14, 1960, was a spacecraft designed to test life-support systems for manned space flight. The initial plan was to remove the vehicle from orbit by retrofiring rocket. On May 19, the retrorocket was fired, the pressure vessel apparently separated from the cabin, but because of improper orientation, the cabin went into a lopsided orbit instead of re-entering the earth's atmosphere.

The payload weight* totaled 10,008 lbs, with the pressure cabin weighing 5,512 lbs. The payload configuration is unknown. The spacecraft was equipped with a "dummy spaceman" and an environmental control system. The satellite contained one transmitter (19.995 MC), which was used for both telemetry and "telephone" systems. A tape of a voice was transmitted to ground stations. Power was supplied by solar and chemical batteries.

*These data are unofficial and were obtained from Soviet news sources. The orbital elements were computed by U.S. agencies.

There were nine separate orbiting pieces of Satellite 1960 Epsilon. The first to re-enter was the last stage rocket body on July 17, 1960. By July 1, 1961, six pieces of metal had re-entered. The payload re-entered on September 5, 1962, leaving one piece of metal remaining in orbit.

Orbital elements for Satellite 1960 $\epsilon 1$ at various stages of its orbit were:

	Apogee (Mi)	Perigee (Mi)	Inclination to Equator	Period (Minutes)
May 16, 1960 (after launch)	228.7	188.5	64.9°	91.1
May 19, 1960 (after retro)	429	191	64.9	94.25
Aug. 14, 1962	160	138.1	64.9	89.3

The Satellite 1960 $\epsilon 1$ Fragments

The principal object recovered from Satellite 1960 $\epsilon 1$ (see figure 1), is crudely disk-shaped, approximately 20 cm in diameter and 8 cm high, with an initial mass of 9.49 kg. Its rounded top surface terminates a solid, squat cylinder 15.1 ± 0.1 cm in diameter. The cylinder is welded to a roughly circular plate, 1.0 cm thick. To the bottom of the plate is attached an irregular layer of material, whose appearance is such as might be expected from solidification of molten droplets of metal in vacuum. Many small fragments similar to the material of this layer were also found near the main body. The circumference of the plate shows evidence of material having ablated away. Part of a shoulder between the cylinder and the plate is also filled with resolidified metal. The shoulder exhibits evidence of such filling around its entire circumference, and many loose fragments fitting into place on the shoulder were found nearby.

Diametrically located on the rim of the plate are two bolt holes, 0.75 ± 0.02 cm in diameter, each with a countersunk hole 2.0 ± 0.1 cm in diameter. One of the bolt holes is not complete, the outer wall of the hole having melted away. A very complete set of photographs, taken soon after recovery, recorded the appearance of the fragment in a systematic sequence of aspects.

The shape of the body is illustrated in figure 2, made after specimens for scientific analysis had been removed. When the body was sawed, a bolt was revealed embedded in the irregular layer (figure 3). One end of the bolt, which has a 6-mm diameter with 1 thread per mm, is threaded into a flanged nut. A second, apparently identical, flanged nut was found in one of the samples used for analysis. Also evident in figure 3 is the way in which the molten metal was deposited, both on the plate and in the shoulder where the cylinder is welded to the plate. The weld is also apparent.

A metallurgical examination of specimens from the object was made by Professors N. J. Grant and B. C. Giessen of the Massachusetts Institute of Technology Department of Metallurgy and by metallurgists at the Brookhaven National Laboratory. Both the cylindrical portion and the plate are ordinary medium-carbon steel. The resolidified irregular layer has a similar composition, except that some of the more volatile trace elements in the steel are reduced in concentration.

The surface of some areas of the irregular layer of metal has a thin white coating. This has been identified by Mrs. Ursala B. Marvin as MgO. When recovered, and for several days thereafter, the irregular layer had a distinct ordor of ammonia. The suggestion has been made that some magnesium nitride may also have been originally present. This would be expected to combine with moisture in the air, releasing ammonia and leaving magnesium oxide.

The successful sequence of events associated with the re-entry of Satellite 1960 $\epsilon 1$ has been a great satisfaction to all involved. Surely such good fortune can be expected only rarely. However, with persistence on the part of all members of the SAO team, particularly the observers around the world, such successes can be repeated.

References

FIREMAN, E. L.
1962. The Ehole meteorite, its acquisition and its radioactivities. Journ. Geophys. Res., vol. 67, pp 2592-2594.

JACCHIA, L. G.
1958. The descent of Satellite 1957 β1. Smithsonian Astrophys. Obs. Special Report No. 15.

Figure 1.--The Manitowoc fragment from Sputnik IV (scale in inches).

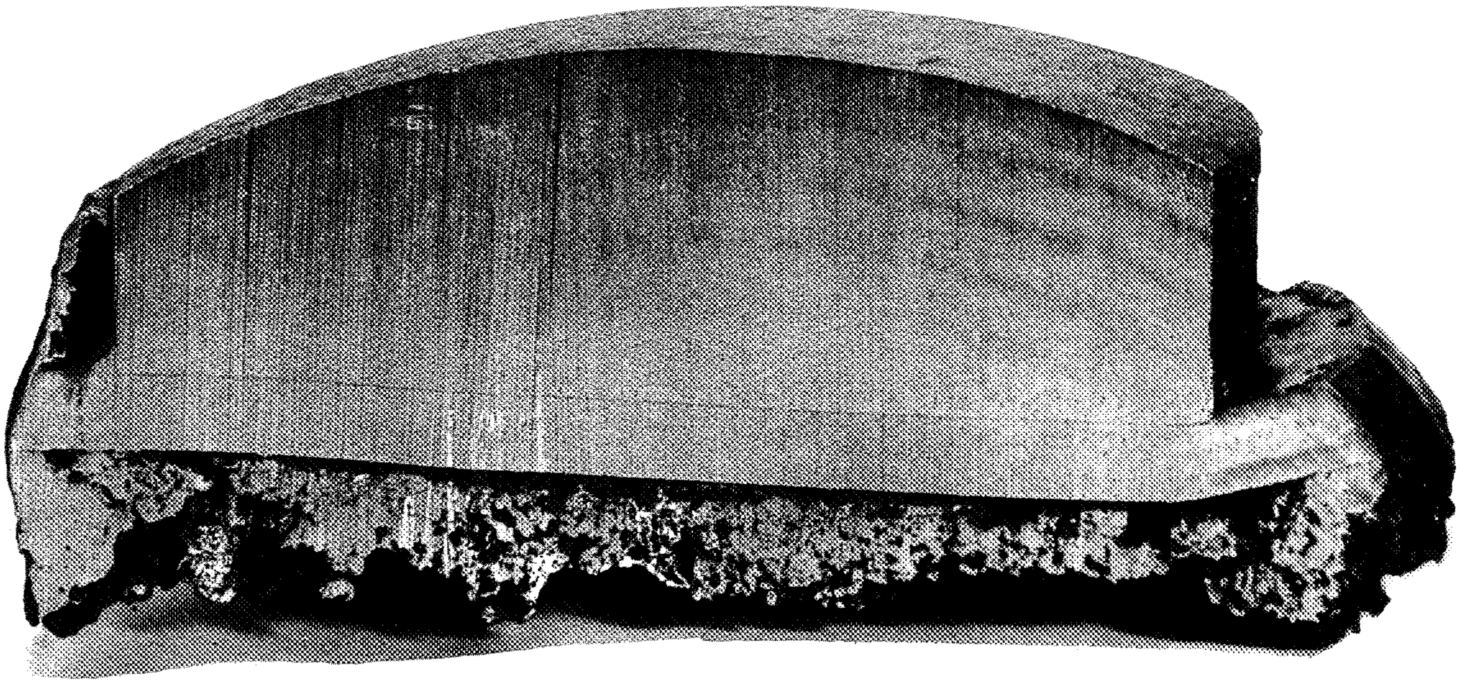


Figure 2.--Section of the Manitowoc fragment.

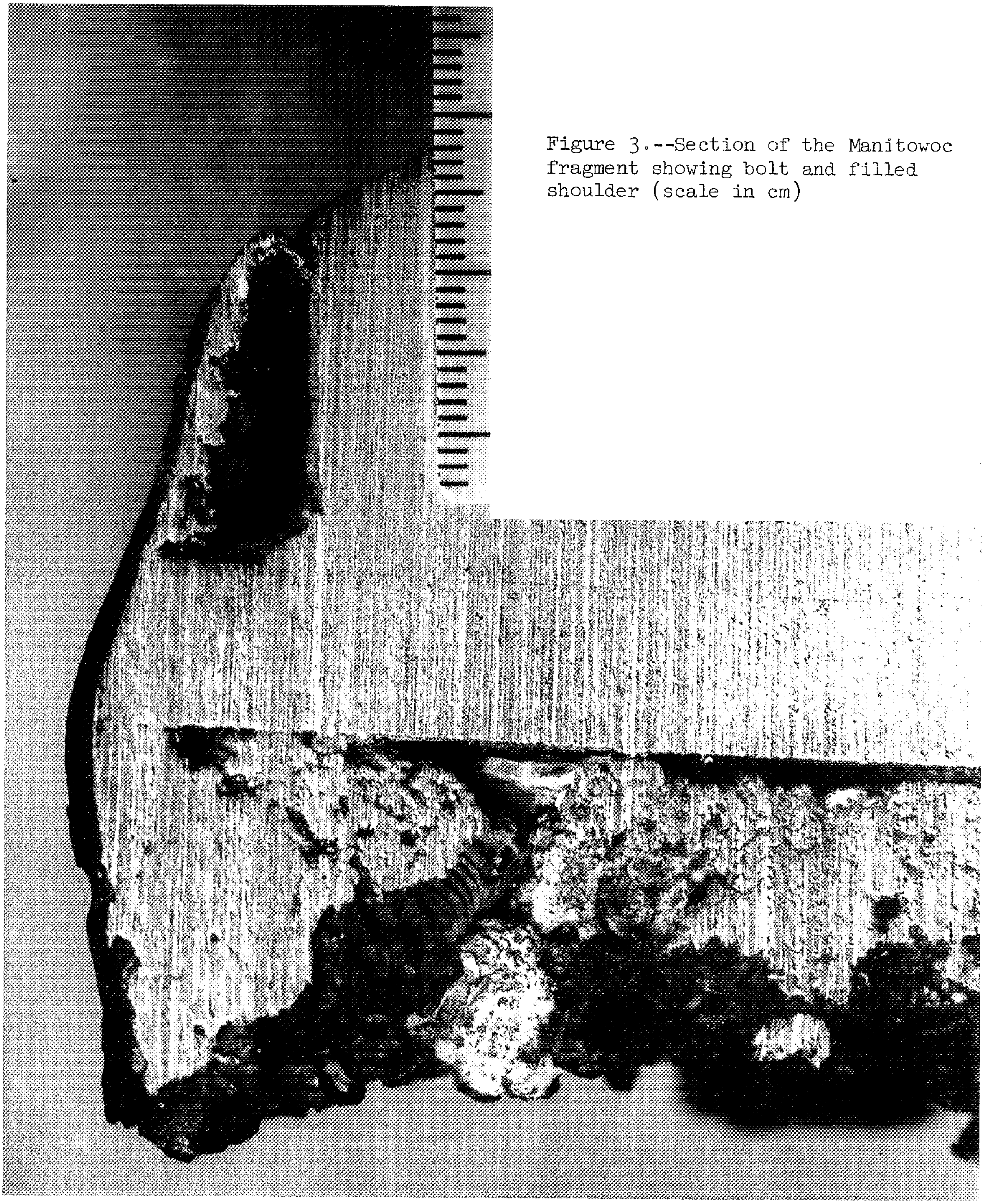


Figure 3.--Section of the Manitowoc fragment showing bolt and filled shoulder (scale in cm)

SPUTNIK IV RE-ENTRY: THE ROLE OF MOONWATCH

Richard C. Vanderburgh[1]

1. Background

Organized Moonwatch re-entry patrols began with the second artificial earth satellite, 1957 Beta (Sputnik II), which re-entered the atmosphere in April, 1958. Moonwatch observers were given one equatorial crossing prediction with the orbit precession rate, and advised to organize patrol shifts to cover the entire sky during the hours of darkness. Observations of re-entry incandescence were reported by Moonwatch teams in Millbrook, N. Y., Milwaukee, Wis., New Haven, Conn., and Bryn Athyn, Pa., and by many isolated observers on land and sea who happened to be in the right place at the right time to witness the beginning of re-entry. Although the object was seen to break up, there were no observations as the fragments descended below about forty miles. Extrapolation placed the probable impact area near the South American coast in the vicinity of Dutch Guiana. Dr. Luigi G. Jacchia of SAO was sent to the area to interview the observers and search for fragments, but no fragments were recovered (Jacchia, 1958).

In March 1960, Moonwatcher Arthur Leonard outlined a prediction method to be used on the re-entry of Satellite 1958 $\delta 2$, which was the forerunner of the method used to track the Sputnik IV re-entry. Although Moonwatch observers throughout the world were alerted, there were no observations of the re-entry of 1958 $\delta 2$ (assumed to have occurred on April 6, 1960).

Further attempts at re-entry patrol were left to the initiative of individual Moonwatch teams until spring 1962, when the planning that led to the successful observation and recovery of Sputnik IV fragments began.

At the third annual Moonwatch Teamleaders Conference, held in Cambridge in May 1962, Dr. Fred L. Whipple, Director of the Smithsonian Astrophysical Observatory, gave renewed emphasis to the visual observing of re-entering satellites as a Moonwatch project. As a follow-up, the Moonwatch Division began to study various ideas that might lead to effective, organized sky patrol.

---

[1]Chief, Moonwatch Operations, Smithsonian Astrophysical Observatory.

Mr. Robert Citron, chief of the SAO Baker-Nunn camera station in South Africa and coordinator of African Moonwatch teams, in June submitted to the Observatory a paper outlining a re-entry program for Baker-Nunn camera stations and Moonwatch teams to provide observational data for lower-atmospheric drag studies.

In July, Moonwatch arranged for Sacramento teamleader Arthur Leonard to spend a week at SAO to consult with Computations and with Moonwatch personnel on development of a trial program for re-entry prediction. From August 6 to 10, Mr. Leonard and programmer Alexis Bakeeff outlined for the IBM-7090 computer a basic program that would produce an output defining the orbital plane at selected latitudes on the Greenwich meridian.

In mid-August, SAO's interest in re-entry observing was the subject of an in-house discussion, at which the following conclusions were reached:

1) The primary reason for SAO interest would be that eventual recovery of orbiting fragments would be of interest to scientists in the fields of radiation and meteoritic studies.

2) Observations of re-entering spherical satellites would aid atmospheric-drag studies; re-entry observations of nonspherical satellites would not be useful, since mass-area ratios would not be known.

3) It would be difficult for Baker-Nunn stations to observe satellites nearing re-entry because of limited visibility and poor predictability.

4) Moonwatch observers would have a better chance for success than would the Baker-Nunn stations, since naked-eye patrols can continuously cover elevated orbits.

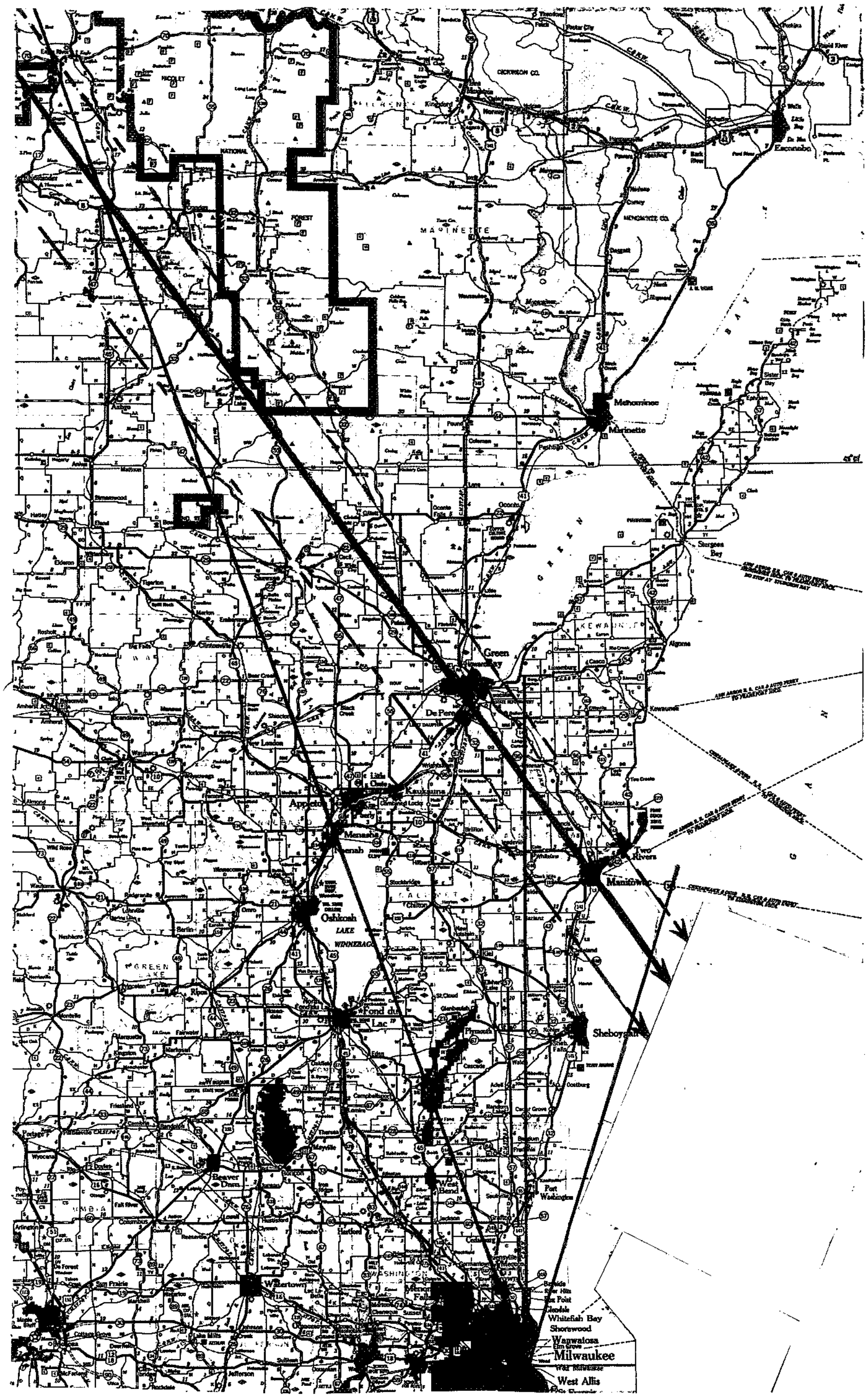
5) As an experiment, the Moonwatch Division should conduct an organized sky patrol in an attempt to observe the next large re-entering satellite, Sputnik IV, predicted by SPADATS to re-enter on or about September 6, 1962.

The basic approach enabled Moonwatch to produce a prediction ephemeris from the best SPADATS elements available on August 27. On August 29 Moonwatch Headquarters air-mailed (see appendix 2) instruction packets to about 750 addressees, including Moonwatch teams, Phototrack members, observatories, colleges, universities, and other interested groups throughout the world. The plan was to telegraph last-minute corrections to key Moonwatch teams. However, by September 3, there were no significant corrections to be made, and the air-mailed predictions were considered valid.

2. Milwaukee team role

On Tuesday evening, September 4, 1962, Mr. Ed Halbach, leader of the Milwaukee Moonwatch team, and his assistant, Mr. Gale V. Highsmith, both professional industrial engineers, held a brief training session at the Milwaukee (amateur) Astronomical Society's observatory to prepare observers for effective re-entry sky patrol. The re-entry ephemeris and worksheet they had received from Moonwatch Headquarters indicated that the orbit plane would be overhead at 8:25 PM local time. The group watched without success until 9:30 PM, when clouds prevented further search. Observers Leonard Schaefer and Raymond Zit were to continue the patrol from the Milwaukee Observatory early the next morning; Highsmith would observe independently from a small hill near his home in downtown Milwaukee. By 4:00 AM, 58 minutes before the predicted zenith time, Highsmith had his homemade theodolite set up. At 4:49 he noticed what at first appeared to be a reddish-orange starlike object low in the northwest. The object then appeared to separate into many pieces. By the time he was able to get the first fix (azimuth 340°, altitude 8°), six pieces were distinguishable in the following pattern: · · ⁝ · •, moving SE, glowing an estimated -6 magnitude before fading rapidly to extinction. Time at 0949:47 UT (September 5, 1962) was recorded with a stopwatch later compared to a radio-received WWV time signal, when the leading and largest object was at an azimuth of true north and an altitude of 12 degrees. By this time only the leading object was still visible; it was followed out over Lake Michigan to an azimuth of 16° and an altitude of 11°, at which point it, too, ceased to be visible (see figure 4). During this same period, observers Schaefer and Zit at the Milwaukee Observatory some twenty miles away were watching the same events. Although they were not able to obtain instrument fixes, their report of naked-eye observations confirmed what Highsmith had seen.

At about this time rural northern Wisconsin sheriffs, patrolmen, motorists, and farmers who happened to be looking up at the unusually clear predawn sky witnessed a spectacular sight: many flaming objects were seen to pass nearly overhead at Eagle River, Three Lakes, Tomahawk, Merrill, Wausau, Abrams, and other communities along the descent path. Inspector Kukanich in Eagle River heard a thunderous noise from the northwest just after seeing 24 red-orange objects disappear to the southeast; others reported similar sightings.



- - - - NORAD GROUND TRACE
RECOVERED FRAGMENT PATH
— - — HIGHSMITH (CALCULATED)
——— HIGHSMITH SIGHTINGS

Figure 4.--Last 100 miles of the satellite

Unaware of what had just been seen in other sections of Wisconsin, patrolmen Ronald Rusboldt and Marvin Bausch were cruising the streets of Manitowoc in their squad car when at 5:30 AM they noticed in the middle of the road a small object resembling in the early dawn light an irregularly shaped piece of cardboard. When they passed again at about 7:00 AM they could see that it was definitely metallic, and they stopped to remove this hazard to driving. They were surprised to find it too hot to hold for very long, but managed to move it to the side of the road. There this unidentified piece of metal remained until the afternoon, when the patrolmen, having since learned from news reports that pieces of a satellite might be expected in their area, went back to retrieve the object. They took it to Inspector Francis J. Lallansach at the Manitowoc Police Headquarters. Personnel at two local metal foundries and a shipyard were queried, but were unable to identify it. Lallansach, who had heard that the Milwaukee Journal was soliciting pertinent reports and finds, dispatched the object with visitor Kenneth Gevers, a salesman on his way back home to Milwaukee. The Journal notified Moonwatcher Halbach, who in turn called Moonwatch Headquarters. Observer Highsmith was commissioned to fly the object to Cambridge, Mass., as local examination had not ruled out the possibility that this piece of metal was indeed a satellite fragment.

Highsmith arrived in Cambridge on Thursday afternoon, September 6. Examinations, which were begun immediately, included tests for material composition, physical dimensions, photography and sensitive tests for radioactive isotopes. During his visit to SAO, Highsmith conferred with Drs. McCrosky, Jacchia, and Veis, describing his observations in detail, and drawing comparisons to the re-entering of Sputnik II, of which he had had a glimpse before it made the final descent near the South American coast four years earlier.

On his return to Milwaukee, Highsmith found his Moonwatch associates busy screening observation reports and specimens. It became apparent that the eye-witnesses rarely understood what they saw, and often their descriptions were grossly in error. For weeks after the re-entry event, the Milwaukee Moonwatch team members and other interested individuals spent many hours of their own time trying to learn as much as they could about the re-entry ground path and the authenticity of purported fragments. Those pieces passing local scrutiny were dispatched to SAO for further examination.

References

JACCHIA, L. G.
1958. The descent of Satellite 1957 β1. Smithsonian Astrophys. Obs., Special Report No. 15.

FIELD INVESTIGATION OF SPUTNIK IV SIGHTINGS AND FRAGMENT RECOVERIES

Walter A. Munn[1]

After the specimen brought to the Smithsonian Astrophysical Observatory had been inspected, I, as a representative of the Observatory was sent to Wisconsin to make further inquiries and to search for additional specimens. Since I will be involved in the SAO Photographic Meteorite Recovery Project, collecting additional specimens and interviewing persons regarding sightings provided me with invaluable experience.

I arrived in Wisconsin on Friday, September 7, made contact with the local Moonwatch representative, and then proceeded to Green Bay to set up a telegraph link with the SAO Communication Center.

I next arranged a meeting with the Manitowoc police chief to discuss details of the recovery and related topics before beginning actual field-work to locate further specimens and to obtain first-person accounts of sightings.

On Saturday, September 8, I went with the chief of police to the site of impact, where we discussed the event and inspected the area. The chief was to return later and make a plaster cast of the impact impression.

Next, I interviewed local residents in the impact area. Rev. Vernon Anderson, pastor of the First Lutheran Church, was very helpful. His wife had hear the impact but, after looking out the window and seeing nothing, she returned to bed. Their son had found a small piece of the satellite on their lawn about 125 feet beyond the impact point. A further search of the area around the Rev. Mr. Anderson's house and on the roof of his house and the church, which was in line with the satellite's apparent track, seemed justified (see figure 5). If a piece had been found on the lawn that far from the parent body, others might be either before or farther down the track. Finding others would tend to prove the authenticity of the main body, whose origin at this point had not been determined conclusively.

---

[1]Assistant Supervisor, Photographic Meteorite Recovery Project, Smithsonian Astrophysical Observatory.

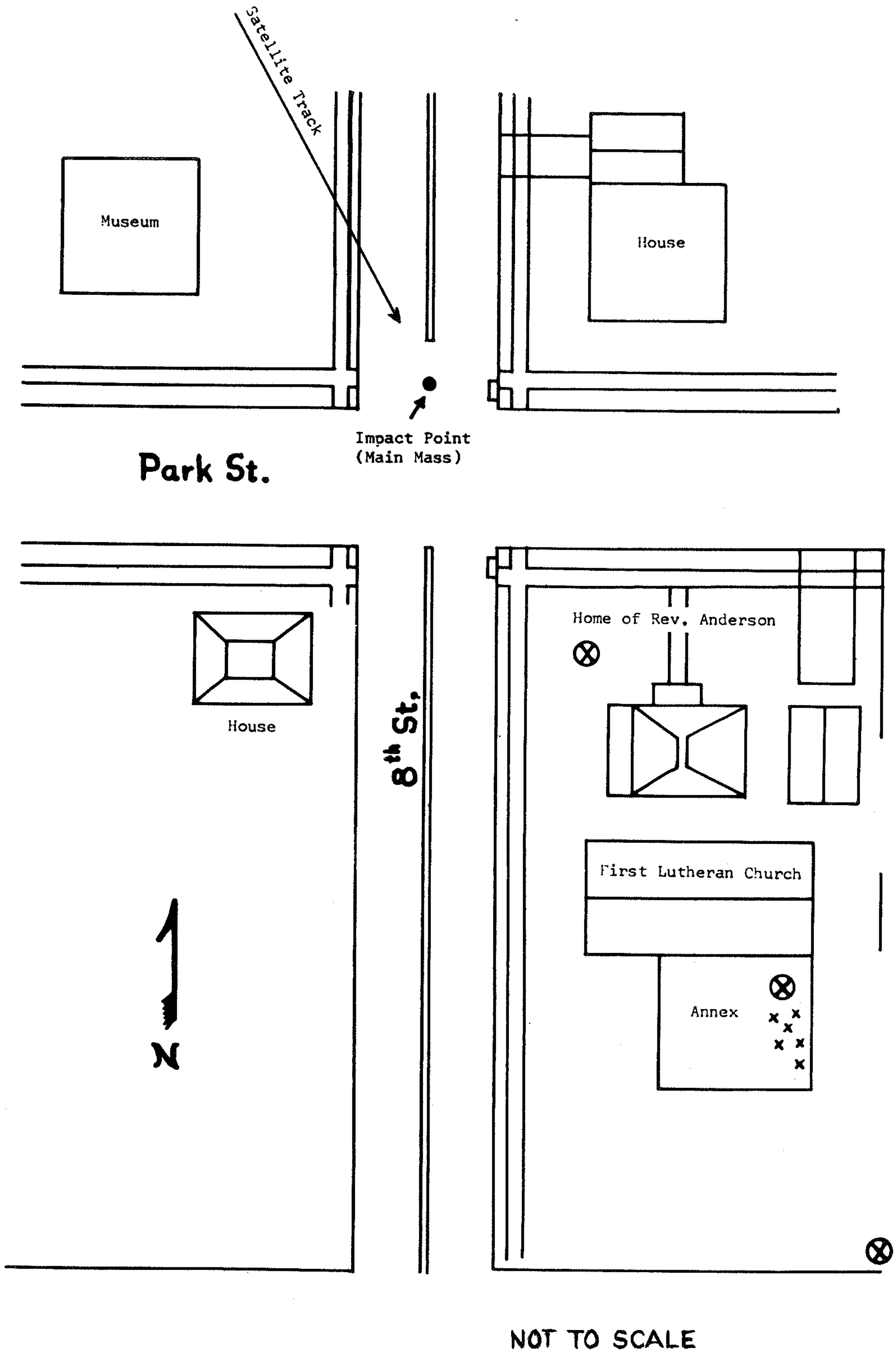


Figure 5.--Block diagram of point of impact of main recovered mass of Sputnik IV and immediate vicinity, Manitowoc, Wisconsin.

A search of the roof of the minister's house brought no success, but the church annex roof produced about 15 small spherules approximately 1/8" in diameter (see figure 6), similar in appearance to the irregular material on the main body. The church annex roof is about 200 feet or more from the impact point. After the roof had been searched, the ground area beyond the church was inspected. In the southeast corner of the church property, about 500 feet from the impact point, two small clusters of metallic spherules approximately 3/8" in diameter and 3/4" long were recovered.

On Saturday noon the chief of police gave me the plaster cast, on which the magnetic compass heading and the satellite's apparent track were inscribed. The heading was determined by the visual sightings and the recovered specimens. (The original plaster cast is now in the possession of SAO; a second casting is held by Police Chief Scherer of Manitowoc. Photographs were also made.)

During the period from September 6 to September 13, I investigated nearly 100 reported visual sightings, ranging north to Ashland, Wis. and south to Milwaukee; west to Eau Claire, and east to Escanaba, Mich. Of this total of 100 about 6 sightings could be reliable, but the over-all picture was not dependable. A clinometer and compass were used in conjunction with maps, but the picture in each person's mind was confused by the number of pieces observed, ranging from 5 to 25 or more strung out one behind the other.

One local resident, a bus driver who was between Escanaba, Mich., and Green Bay, Wis. (approximately 88° W longitude and 44°48' N latitude), offered the following account:

"As we watched, the lights began to spread out, one behind the other. I continued to drive south until I was about 1/2 mile from the intersection of highways 41 and 141. The time was about 5:00 AM. The lights became brighter, and then we counted 25 or 30 of them passing almost directly over the bus; they were traveling at a great rate of speed. As the first one disappeared over the bus, I looked out the windshield, but could not see them. I looked out the left side window, and saw them in the direction of Manitowoc."

This sighting can be expressed more technically in the following terms: azimuth 335°, visible for approximately 1.5 minutes with a separation of the objects of approximately 50 to 60°. The minimum zenith angle of the mainflight path could not have been at a zenith distance of more than 20° when the azimuth was 245°.

The sightings would have been more accurate if observers had been able to concentrate on only one item of reference.

Figure 6.--Spheroids found on roof of First Lutheran Church, Manitowoc, Wisconsin (scale in inches).

On September 13, I checked on the details of a 14-lb specimen recovered in Sheboygan, Wis. I talked with Mr. Kenneth Graves, who had recovered the specimen near the Plastics Engineering Company's loading dock. This was not the original place of discovery; the specimen had been found at the firm's resin plant about a mile away. I inspected the original point of discovery, but found no evidence to indicate either impact or particles.*

Back at the Observatory, the Moonwatch staff reconstructed from these and other data the probable last-half revolution of the satellite (see figure 7).

---

*The over-all evidence that this was an actual fragment of the satellite was insufficient to warrant extensive analysis.

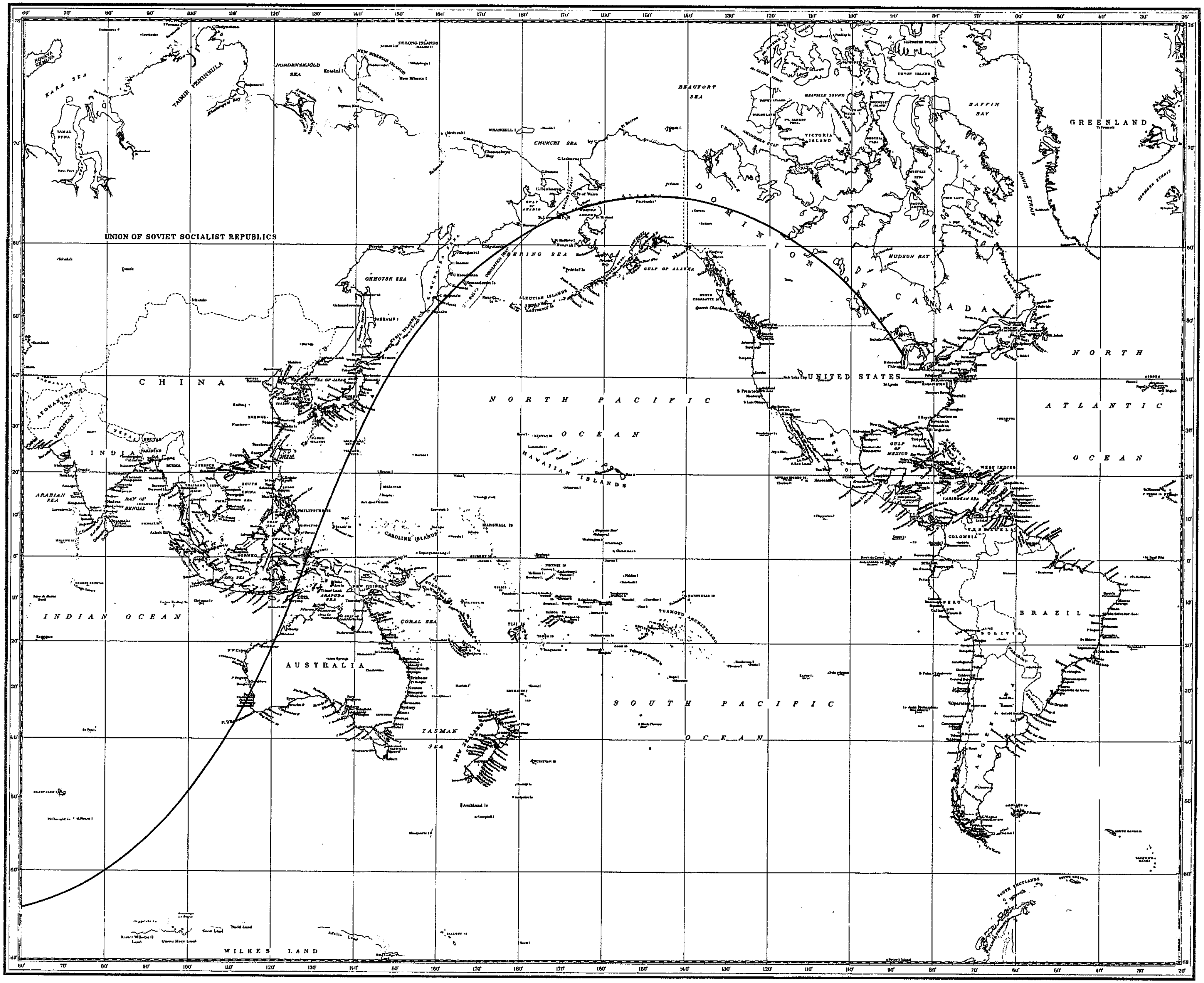


Figure 7.--Last half-revolution of the satellite.

RADIOACTIVITIES IN THE MANITOWOC FRAGMENT

David Tilles[1], Edward L. Fireman[1] and James DeFelice[1]

Energetic nucleons (protons, helium nuclei, neutrons, etc.) produce nuclear reactions when they interact with the nuclei of materials. These nuclear reactions produce a variety of different radioactive isotopes. Above the earth's atmosphere there are many energetic particles, including "galactic" cosmic rays, solar-flare accelerated nuclei, and geomagnetically trapped or Van Allen belt particles.

Thus objects bombarded by the high-energy corpuscular radiations in space may, if exposed long enough, contain measurable amounts of many radioactive isotopes. The concentrations of various radioactive isotopes depend on the flux of particles, the energy spectra of the particles, the original shielding of the sample studied, the duration of exposure, and the time elapsed since recovery.

The atmosphere effectively shields the surface of the earth from most of the energetic particles. The presence of particular radioactive isotopes can be used both as a test of whether an object was recently in space and as a crude indicator of how long.

Conversely, from studies of the concentrations of radioactive isotopes in objects of known orbit, we can learn things about the intensity, energy spectra, and time and spatial dependence of corpuscular radiation. Extensive studies of radioactive and stable isotopes in meteorites and in recovered satellites have contributed to our present knowledge of corpuscular radiation in the solar system.

Research groups at the Smithsonian Astrophysical Observatory, the Los Alamos Scientific Laboratory, the Air Force Cambridge Research Laboratories, the Carnegie Institute of Technology Chemistry Department, and the Brookhaven National Laboratory have all measured radioactivities in the fragment of steel found in Manitowoc. The positive results obtained by all of these groups indicate quite clearly that the Manitowoc fragment was above the earth's atmosphere for a substantial length of time. No other method of identification provides such strong evidence of an object having been in space. The measurements of radioactivity, together with the evidence outlined in other sections of this report, suggest very strongly that the Manitowoc object was in fact a piece of Satellite 1960 ε1.

---

[1] Smithsonian Astrophysical Observatory.

Investigations are continuing. A preliminary presentation of scientific results is tentatively scheduled for the national meeting of the American Geophysical Union at Stanford University in December 1962. The tentative program with titles and authors of all papers is given in appendix 1.

Abstracts of these talks have been published by the AGU, and the detailed results will be published in the suitable scientific journals.

APPENDIX 1

An extra session on Planetary Sciences has been scheduled for the December, 1962, meeting of the American Geophysical Union at Menlo Park, Stanford, Calif. The schedule for this session is published on page 423 of the American Geophysical Union Second Western National Meeting Program, 1962 (preprinted from Transactions AGU, vol. 43, no. 4, Dec., 1962). Abstracts of the papers to be presented are published in the pages noted below.

VII. Scientific Results from a Naturally Recovered Satellite Fragment (David Tilles, Smithsonian Astrophysical Observatory, Cambridge, Mass., Chairman)

(1) BILL C. GIESSEN and NICHOLAS J. GRANT (Massachusetts Institute of Technology, Cambridge) Metallurgical Investigation of Sputnik IV Fragment (p.457).

(2) URSULA B. MARVIN (Smithsonian Astrophysical Observatory, Cambridge) Mineralogy of the Melted Portion of Sputnik IV (p.457).

(3) J. DeFELICE, E. L. FIREMAN, and D. TILLES (Smithsonian Astrophysical Observatory, Cambridge) H^3 and A^{37} in a Fragment of Sputnik IV (p.457).

(4) J. P. SHEDLOVSKY and J. H. KAYE (Carnegie Institute of Technology, Pittsburgh) Radioactive Nuclides Produced by Cosmic Rays in Sputnik IV (p.457).

(5) ERNEST C. ANDERSON and M. A. VAN DILLA (Los Alamos Scientific Laboratory, University of California, Los Alamos) Gamma-Ray Spectrometry of a Sputnik IV Fragment (p.457 f.).

(6) JOHN WASSON (Air Force Cambridge Research Laboratory, Bedford) Radioactivity in Sputnik IV Fragment (p.458).

(7) O. F. KAMMERER, R. DAVIS, Jr., H. L. FINSTON AND J. SADOFSKY (Brookhaven National Laboratory, Upton) Chemical and Metallographic Studies of Sputnik IV Fragments (p.458).

NOTICE

This series of Special Reports was instituted under the supervision of Dr. F. L. Whipple, Director of the Astrophysical Observatory of the Smithsonian Institution, shortly after the launching of the first artificial earth satellite on October 4, 1957. Contributions come from the Staff of the Observatory. First issued to ensure the immediate dissemination of data for satellite tracking, the Reports have continued to provide a rapid distribution of catalogues of satellite observations, orbital information, and preliminary results of data analyses prior to formal publication in the appropriate journals.

Edited and produced under the supervision of Mrs. L. G. Boyd and Mr. E. N. Hayes, the Reports are indexed by the Science and Technology Division of the Library of Congress, and are regularly distributed to all institutions participating in the U.S. space research program and to individual scientists who request them from the Administrative Officer, Technical Information, Smithsonian Astrophysical Observatory, Cambridge 38, Massachusetts.